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(18) AFOSR TR- 81-0585) LEVEL (12) Measures of Resource Allocation
Evoked Response Effects of Primary Task Load
Evoked Response) INTRODUCTION (16) 3313 17 D91. 9 Final re

The work-load paradigm (Ogden, et al., 1979) has been used extensively in research concerning the psychological aspects of evoked potentials (Donchin, 1976, 1977). Typically a perceptual motor task is used as the primary task while an uncertainty task such as the odd-ball (Sutton, 1965) paradigm is used as a secondary task. The subject is required to perform the primary task at pre-determined levels of difficulty while attending to rare occurring auditory stimuli. The evoked potential is measured in response to the target stimuli and an effort is made to infer, from components of the event related potential (ERP), psychological parameters such as attention and arousal. A determination is made as to the distribution of resources assigned to the tasks. Isreali et al (1978) indicated that increasing the primary task load resulted in a precipitous drop in the P₃ component of ERP. Results of our study (Elfner, 1978) showed no degradation in the P₃ wave as a function of task difficulty on the primary task. The task in the latter study was to track a forced-function moving target on a cathode ray tube display. Subjects were instructed in the task to achieve stable performance levels at the difficulty levels employed; the major difference in the secondary task was that a random inter-stimulus interval (ISI) was employed. Donchin typically employs a fixed ISI. It would appear from the results of Elfner (1978) that the presence of random ISI in the secondary task considerably increases the resource allocation applied to the secondary task as evidenced by the large P₃ component of ERP. (10) L. F. 12/14/79 ✓ R. R. Johnson
W. R. Hartman

Schwent (1976) has shown that selective attention to target stimuli can be demonstrated in the N₁ - P₂ component of ERP. The study found that attentional changes in ERP were noted in sequences with relatively short interstimulus intervals (200 - 500 msec) but with ISI of a second or longer little or no selective

Response Measures of Resource Allocation:
Effects of Primary Task Load. II.

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attention was shown in $N_1 - P_2$. Also low stimulus intensity levels both absolute and masked threshold, could be used to demonstrate the latter effect.

The present study was undertaken to assess the effect of flight stimulation on the ability to attend to rare occurring auditory targets. It is assumed that as the flight simulation task is made more complex less resource will be available to track the auditory targets. At the cortical level the $N_1 - P_2$ and the P_3 component should show a decrease in amplitude since attention will supposedly be diverted to the primary flight simulation task.

METHOD

Subjects

Three male normal hearing students ranging in age from 24 to 27 were trained in operating a flight simulator under the experimental conditions. The subjects were also given training in discrimination of the phonemic stimuli. One of the subjects (VP) was a student pilot.

Apparatus

A GAT-1 general aviation flight simulator was used for the primary task. The GAT-1 simulated instrumentation and sensory qualities of flight in a single seat, single engine fixed wing aircraft. Normal operation of this simulator produces approximations to sensory events in visual, auditory and vestibular modes including changes in attitude in three planes. Operation of the simulator requires consistent and complex sensorimotor coordination, the difficulty of which is dependent upon several easily controlled variables. One of these, which served as an independent variable in this study, is "air roughness." This variable controls the rms amplitude of a near-gaussian signal which is superimposed on signals to the drive motors which operate on the three spatial axes.

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The effect is to vary the degree and rate of corrections required of the simulator pilot. Instantaneous values corresponding to pitch, bank, bearing, altitude, airspeed, climb rate, slip and engine rpm were sampled every five seconds and recorded by a PDP-12 computer. Blinders were placed over the windows of the simulator, forcing the pilot to function without visual referents other than instruments. Auditory stimuli (mostly engine noise) produced by the simulator were deactivated to avoid unnecessary masking of experimental stimuli.

Experimental auditory stimuli were presented to the subject bi-aurally through a pair of Grason-Stadler HD-30 earphones. Stimuli were reproduced from tape using a Sony TC-270 tape recorder. A push button was mounted on the flight simulator yoke for subject responses to secondary task stimuli.

EEG signals were amplified by a Grass P-15 amplifier located inside the cockpit, and subsequently by a Tektronix RM-122 approximately 20 feet from the simulator. Signals from these were monitored on a Nicolet model 1074 signal averager and recorded on a Hewlett-Packard (Sanborn) model 3917-B eight channel FM tape system. The FM recorder was also used to simultaneously record frequency coded stimulus trigger points and to record the subject's responses to auditory stimuli. EEG signals were subsequently played back from the FM tape, sorted by stimulus type (as indicated by the trigger tones) and averaged. Figure 1 presents a block diagram of the experimental apparatus.

Place Figure 1 about here

Stimulus Preparation

Auditory stimuli were pre-recorded sequences of samples from the phonemic continuum /pa/-/ba/. These samples were prepared at Haskins Laboratories using

a cross-splicing technique. In brief, this technique involved substituting progressively larger segments of the prevocalic portion of a live recorded sample of /pa/ for equal segments of a live recorded (from the same speaker) sample of /ba/. Slicing was carried out by computer operating on the digitized waveforms. Splicing points were chosen to correspond with zero crossings between glottal pulses of the vocalic signal. This technique achieves manipulation of voicing onset time (VOT) while minimizing distortion of vocalic components. Total duration for each of the stimuli was 500 msec.

Stimulus sequences were assembled using 3 VOTs, two of which were representative of the endpoints of the perceptual /pa/-/ba/ continuum. The third VOT used lay in the transition zone of the /pa/-/ba/ continuum. Thus a stimulus having a comparatively long (19 msec) VOT was included because in prior testing it was perceived in a high proportion of instances as /pa/. A stimulus having a comparatively short (10 msec) VOT was included because in prior testing it was perceived in a high proportion of instances as /ba/. A third stimulus (14 msec VOT) was included because it was categorized as /pa/ or /ba/ at nearly chance rates. Stimulus sequences were recorded using random interstimulus intervals with a mean value of 4.68 seconds. Stimulus order was random.

Two stimulus sequences were used in this study. In one sequence the non-target (10 msec VOT) appeared 143 times while the target stimuli (14 and 19 msec VOTs) were each presented 16 times resulting in a combined target probability of .183 (nominally .2). In the other stimulus sequence the frequency of each target stimulus was doubled, resulting in a combined target probability of .366 (nominally .4).

Procedure

Subjects were given practice in operating the flight simulator under both

smooth and rough air conditions until reasonable proficiency was attained in straight and level flight. They were also given experience in listening to stimulus sequences similar to those used in the experiment. At the beginning of each experimental session the subject was fitted with EEG electrodes at the vertex (active), left mastoid (referent) and right mastoid (ground). Resistance between any pair was kept below 5 k ohms.

Air roughness was set before the session, with the subject's knowledge. The subject was instructed to maneuver the simulator to a 1,000 foot altitude and maintain straight and level flight heading due south. When in this state the subject signalled, using the pushbutton on the yoke. At this time computer sampling of flight status, recording of ongoing EEG and the stimulus tape were all started. The subject was instructed prior to each session to respond immediately with one button press each time he heard /pa/. Voltage of the audio signal to the subject was monitored to provide a stimulus presentation level of 45 dts SPL. The subject was made aware that his primary task was maintenance of straight and level flight but that he should make his best effort on the auditory task.

Each subject performed in one session for each combination of primary task difficulty and target stimulus probability.

RESULTS

Only the vertex evoked potential (EP) results are presented in the present paper. Figures 2-7 show the evoked potentials for the three subjects for the twelve experimental conditions.

Place Figures 2-7 about here

Note that the total elapsed time shown for the traces is approximately 1600 msec.

A perusal of the presented figures demonstrates the following in terms of amplitude of the $N_1 - P_2$ component. Higher probability of occurrence of a target resulted in a greater amplitude of $N_1 - P_2$. This result is consistent for all subjects and each of the experimental condition orthogonal to target probability.

The amplitude of the $N_1 - P_2$ component shows no consistent change as a function of rough versus smooth air. Also the amplitude shows no consistent change with VOT.

The latency of the N_1 component in the EP demonstrated no significant change over the experimental conditions.

DISCUSSION

The failure to consistently find a P_{300} component in the event related potentials is difficult to comprehend. A perusal of the data shows that the VOT of 10 msec, which is a non-target, was as likely to evoke a P_{300} as was a VOT of 19 msec which was ordinarily perceived quite strongly as a target. That a VOT of 14 msec did not produce a consistent P_{300} is explicable in that this particular VOT is confusable in terms of being a target or non-target. One would predict that the P_{300} would be more prominent in the smooth air flight simulation condition. The prediction is that more "attention" can be directed toward the secondary task under low load on the primary task (flight simulation). The

prediction is not borne out by the data. That is the P300 does not appear to be of greater amplitude or shorter latency in the smooth air flight simulation. Behavioral data has not been analyzed hence only a prior consideration can be used in analyzing the secondary task effect. That is until hits and false alarms and reaction times are determined an interpretation of the effects on the secondary task are speculative at best.

No consistent effect of air roughness on simulator performance was noted. This is particularly important for altitude and bearing since these two measures were stressed as critical to flight performance. That is, the subject was trained to maintain bearing and altitude. That the means over the roughness condition are not significantly different from smooth air is of importance. It is much more difficult to maintain heading and altitude under rough air conditions. Hence one can assume that the subjects were indeed putting out more effort on the simulation during the rough air condition. This result holds for all subjects in the study.

Although P300 component shows no consistent trend over the experimental conditions of the N₁ - P₂ component shows, there is clearly an increase in amplitude for the high probability versus low probability of target occurrence.

The result most difficult to understand is the finding of a larger amplitude N₁ - P₂ component for the higher probability target occurrence. It is possible that with the particular auditory stimuli used in the study, it was difficult to discriminate between target and non-targets. This would also explain the lack of a consistent P300 component in the data. The conclusion to be drawn would be that the auditory task was not an expectancy type task but rather a series of auditory events which were signals that provided a non-selective attention response from the subject. The difference in N₁ - P₂ amplitude could then be

explained in terms of a general arousal. The low probability condition being perceived as a series of /pa/ sounds while the high probability of occurrence produced some perception of /ba/ sounds. The occasional perception of the /ba/ sound would not be appreciated by the recording system since all VOT of 14 and 19 msec were averaged in the target data.

FIGURE CAPTIONS

Figure 1 A block diagram of the apparatus.

Figure 2 Evoked Potentials for probabilities of .2 for each of the two targets and .6 for the non-target for subject V. P. Each curve is an average of 32 responses.

Figure 3 Evoked Potentials for probabilities of .1 for each of the two targets and .8 for the non-target for subject V. P. Each curve is an average of 32 responses.

Figure 4 Evoked Potentials for probabilities of .2 for each of the two targets and .6 for the non-target for subject J. M. Each curve is an average of 32 responses.

Figure 5 Evoked Potentials for probabilities of .1 for each of the two targets and .8 for the non-target for subject J. M. Each curve is an average of 16 responses.

Figure 6 Evoked Potentials for probabilities of .2 for each of the two targets and .6 for the non-target for subject G. S. Each curve is an average of 32 responses.

Figure 7 Evoked Potentials for probabilities of .1 for each of the two targets and .8 for the non-target for subject G. S. Each curve is an average of 16 responses.

ACKNOWLEDGEMENTS

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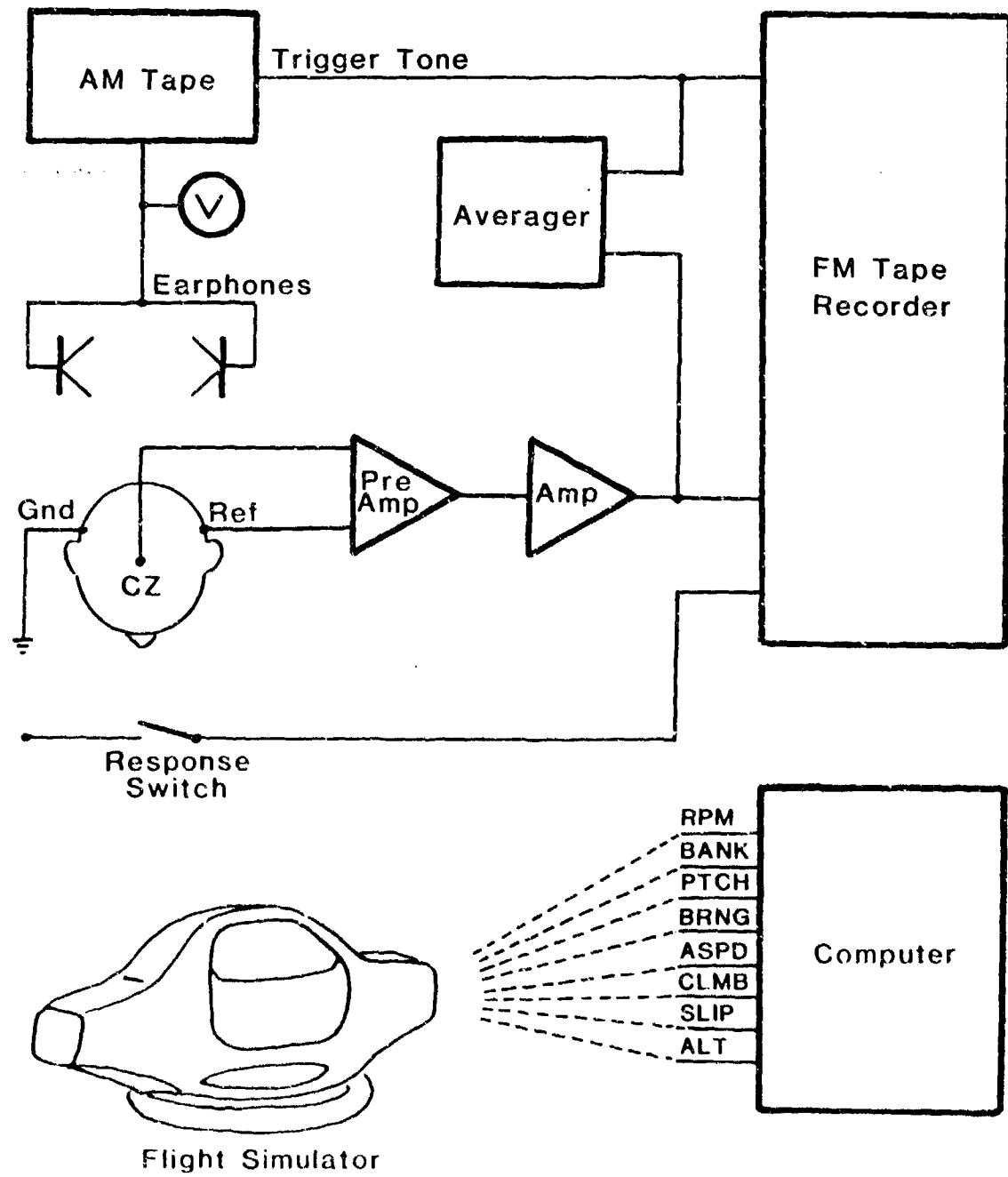
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V.P.

P=.2

ROUGH AIR

VOT=10 msec

Stim. on

14 msec

19 msec

SMOOTH AIR

VOT=10 msec

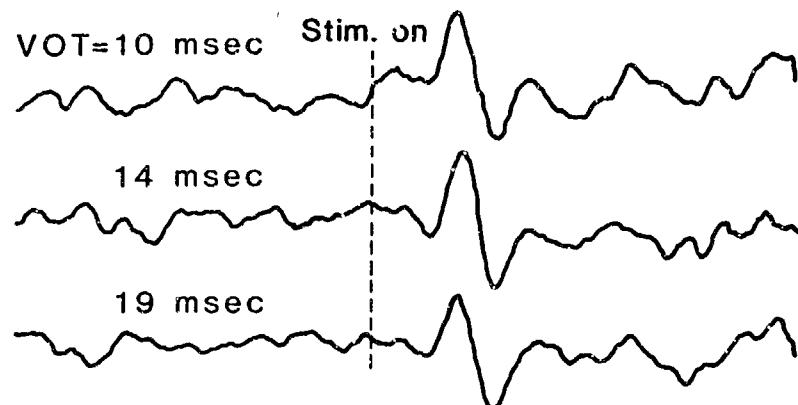
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19 msec

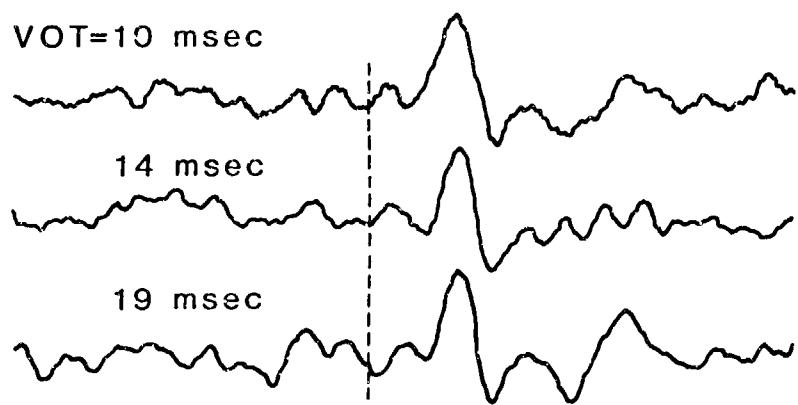
100 μ V

400 msec

V.P.
 $P=.4$
ROUGH AIR



SMOOTH AIR



$100 \mu V$

400 msec

J.M.
 $P=.2$
ROUGH AIR

VOT=19 msec

Stim. on

14 msec

10 msec

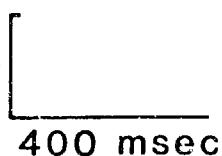
SMOOTH AIR

VOT=19 msec

14 msec

10 msec

100 μ V



J.M.

P=.4

ROUGH AIR

VOT=10 msec

Stim. on

14 msec

19 msec

SMOOTH AIR

VOT=10 msec

14 msec

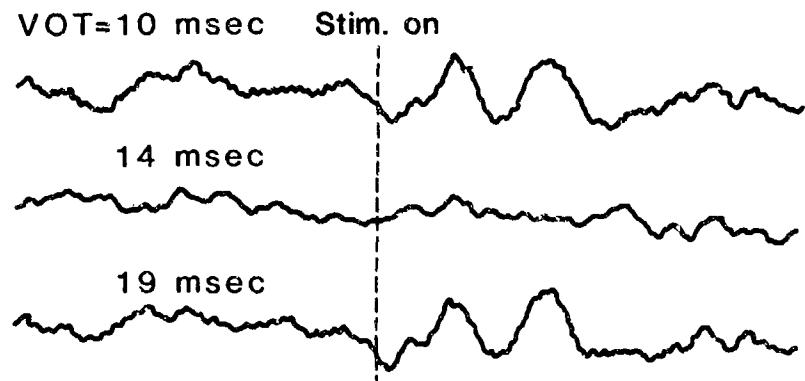
19 msec

100 μ V

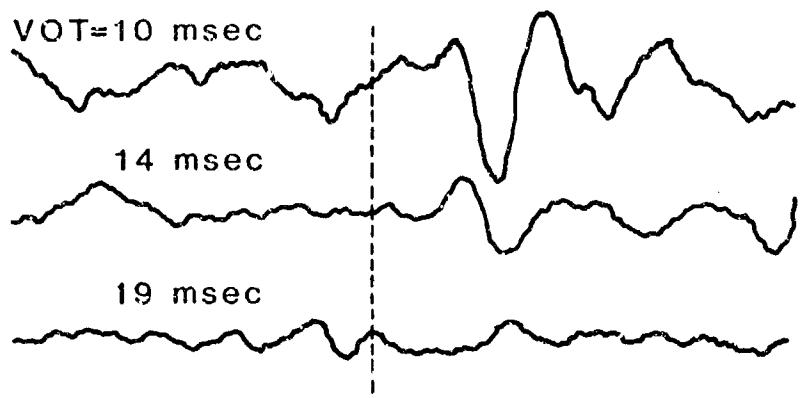
400 msec

400 msec

G.S.
 $P=.2$
ROUGH AIR



SMOOTH AIR



100 μ V

400 msec

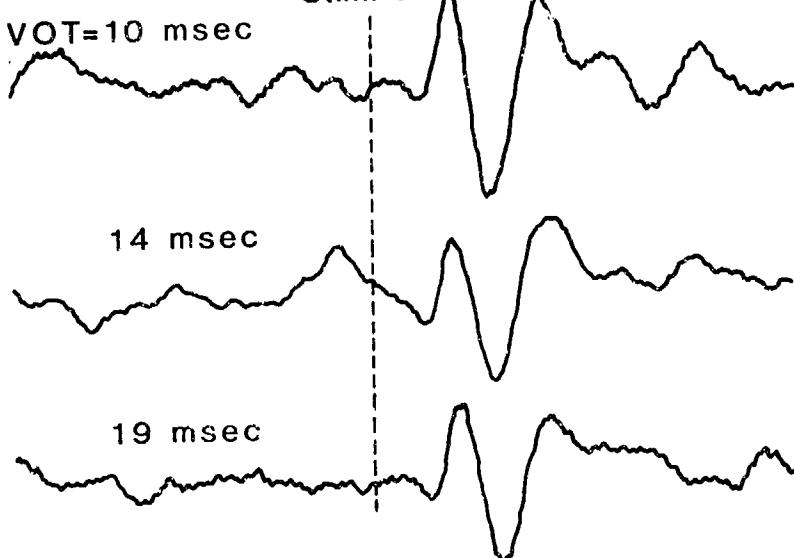
G.S.

P=.4

ROUGH AIR

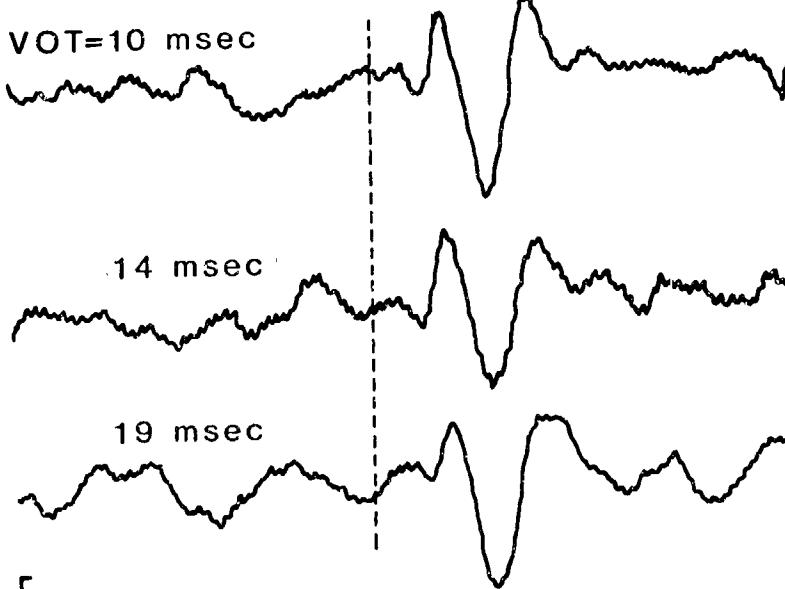
VOT=10 msec

Stim. on



SMOOTH AIR

VOT=10 msec



100 μ V

400 msec

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <u>Summary</u> Late components of the evoked potential to auditory signals were recorded from three human subjects. The work-load task employed was to respond to rare auditory stimuli while flying a Link trainer under condition of smooth and rough air. No consistent p300 component of the waveforms was found across conditions. The N ₁ - P ₂ component of the waveform was noted in most data. The amplitude of the latter component of the evoked potential was greater for high probability of target occurrence than for low probability of occurrence. (Over-)		

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20. No systematic difference in amplitude of $N_1 - P_2$ was noted as a function of air roughness.

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